

3 Dimensional Virtual Modelling of Human Femur Bone with Prosthetic Plate and Screws

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Abstract— Femur bone is the longest and stronger bone in the human body. This bone is contained a linear-elastic, isotropic and homogeneous material of calcium phosphate. It needs to support maximum weight of the body in between hip joint and knee joint during different mode of body posture. Firstly 3 dimension geometric model of femur bone, prosthetic plate and screw is generated in Solid works CAD software which seems to define high mode of difficulty for generating the bone model. The objective of femur bone CAD model is identified the maximum stresses and deformation zone by applying the static load into the finite element ANSYS software. Further femur bone is provided a single crack at maximum stressed zone implanted with prosthetic bone plate and screws.

Keywords— Femur bone, Prosthetic, Traumas, Geometric Model, Dynamic Simulation.

I. INTRODUCTION

An orthopedic implant is a medical technique developed to replace a missing joint or bone or to support a fractured bone. The medical implant is mainly fabricated using various metal alloys for strength covered by the plastic. Two types of fixation generally used- external fixation and internal fixation. In external fixation, metal pins that penetrated bone and protruded through the skin could be connected to an external clamp device, which would allow for stabilization of these pins and thus the bone fragments are attached to it. Internal fixation is the technique in orthopedics that involves the surgical implementation of implants for the purpose of repairing a bone. In the human body at birth, there are over 270 bones, but many of this collapse together during development, leaving a total of 206 separate bones in the adult, not counting numerous small independent bones [1]. In the condition of knock knee the femurs converge so much that the knees touch one another. The femur is the longest and by most measures, the strongest bone in the human body. Among the femurs head, shaft and tibiae, shaft of the femur body is the strongest organ of it. Its length on average is 26.74% of a person's height, a ratio found in both men and women and most ethnic groups with only restricted variation [2]. The femur is

categorized as a long bone and comprises a diaphysis, the shaft (or body) and two epiphysis or extremities that distinct with adjacent bones in the hip and knee as shows in Fig.1.

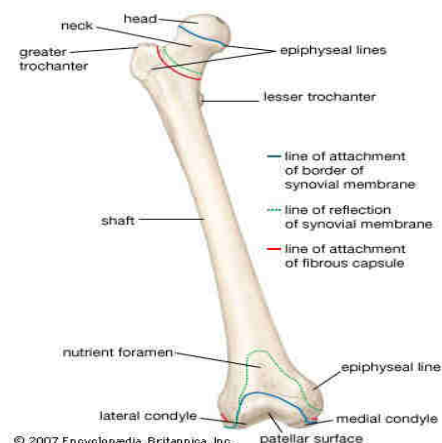


Fig.1 Femur bone anatomy [2]

Finite element is used in the solution of the model in ANSYS software. The finite element model comprises all the nodes, elements, material properties, real constant, boundary conditions, and other features that are used to represent the physical system.

II. GEOMETRY GENERATION

To study the structural analysis of the fractured femur bone, the model is generated using the 3-Dimension scanning technique of the femur bone, prosthetic plate and screw. Solid works and ANSYS 15 software used for modeling. Firstly standard dynamic compression plate and screws purchased from market and measured essential dimensions to draw a three dimension model of plate and screw in solid works software with the help of instruments.

2.1 Dimension of the femur bone

Table.1 Measuring parameters of right femur [4]

Measuring Parameters	Right femur
Maximum length (L_1)	416.8 ± 68.6 mm
Trochanter length (L_2)	402.6 ± 28.1 mm
Collo-diaphyseal angle (Θ)	$127.6 \pm 3.3^\circ$
Proximal breadth (B_1)	90.2 ± 7.6 mm
Head vertical diameter (D_1)	45.2 ± 4.0 mm
Head transverse diameter (D_2)	44.7 ± 4.1 mm

Neck vertical diameter (D_3)	30.7 ± 3.6 mm
Neck transverse diameter (D_4)	26.3 ± 3.1 mm
Midshaft circumference (D_5)	86.2 ± 6.5 mm
Midshaft antero-posterior diameter (D_6)	27.1 ± 3.0 mm
Midshaft transverse diameter (D_7)	26.4 ± 2.4 mm
Distal breadth (B_2)	76.8 ± 5.9 mm

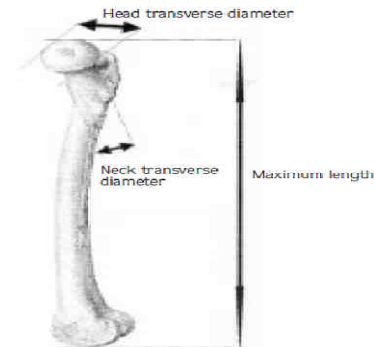


Fig.1: The maximum length, neck transverse and head transverse diameter

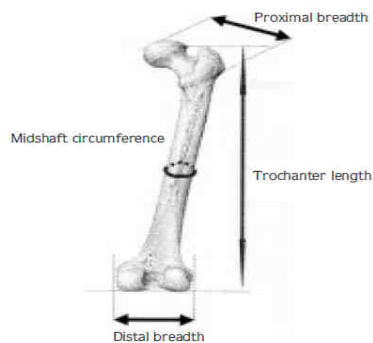


Fig.2: The distal breadth, Trochanter length, mid-shaft circumference and proximal breadth

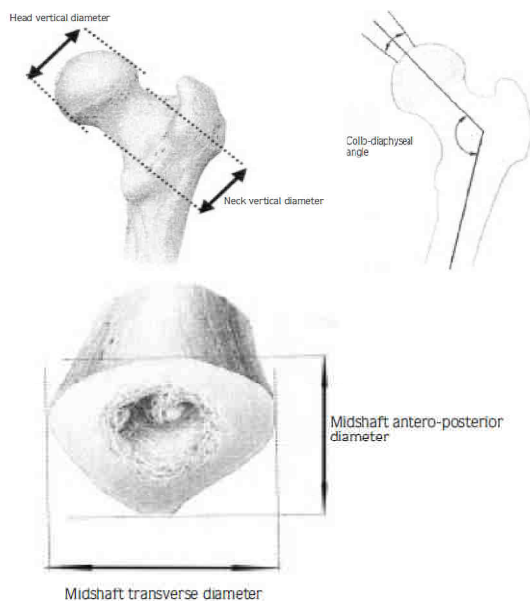


Fig.3: The head vertical diameter, neck vertical diameter, the collo-diaphyseal angle, & the mid-shaft transverse diameter and mid-shaft antero-posterior diameter

2.2 Design of femur bone in CAD

To obtain the 3D model, Solid-works was used. It is CAD software of 3rd generation [7]. Using the measurements made on a real bone and by making observations of the profile, some simple shapes are developed. Then the process of modelling [6] starts.

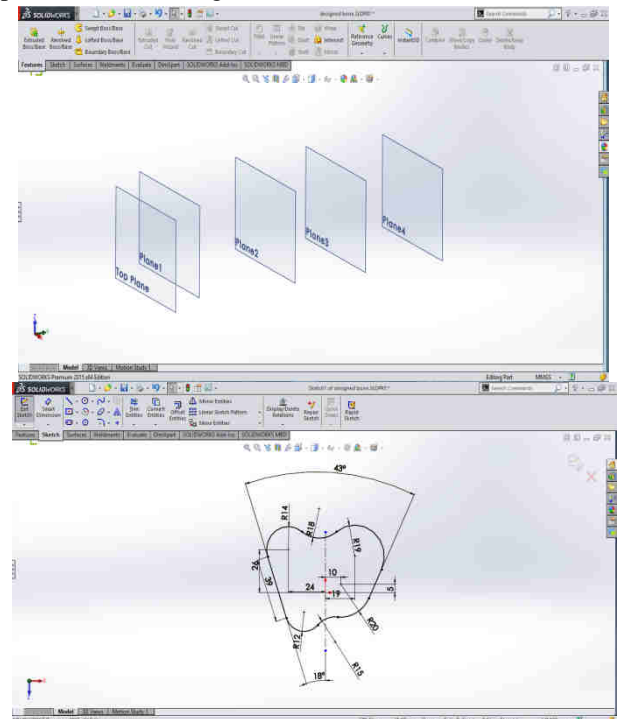


Fig.5: Define five reference plane to model a femur bone & Sketch of femur head cross section in first plane

Initially, we defined five reference plane as shown in Fig.5 (Top plane, and rest at a distance of 40, 190, 300 and 420 mm distance from top plane on same side). First sketch is defined in plane 1 using edit sketch command with curve and spline features are used in Fig.5. In same way following sketches were defined in plane 190, 300 and 420. Using the command Loft Boss/Base the defined sketches were united to a single solid body. Second sketch of femur bone middle shaft cross section is defined in plane 2 using edit sketch command with curve and spline features are used in Fig.6.

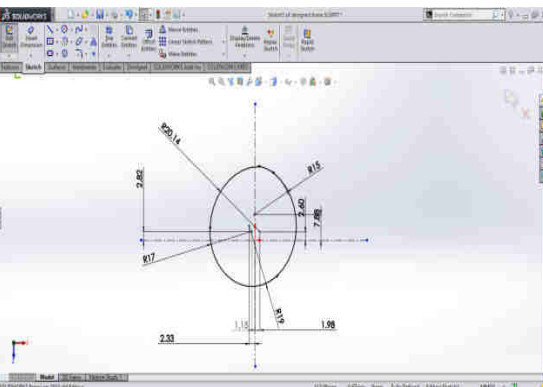
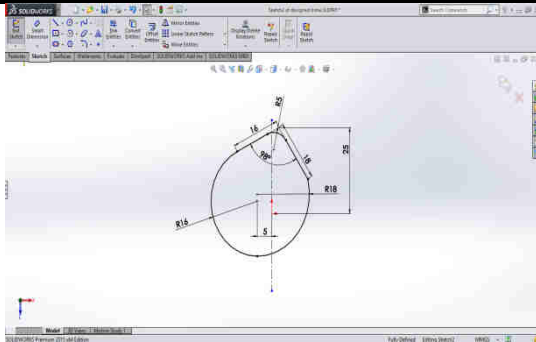


Fig.6: Sketch of femur middle shaft cross section

Using the command Loft Boss/Base the defined sketches were united to a single solid body. Third sketch of lower end of cortical end of femur bone cross section is defined in plane 3 at 300mm using edit sketch command with curve and spline features are used in Fig.7.

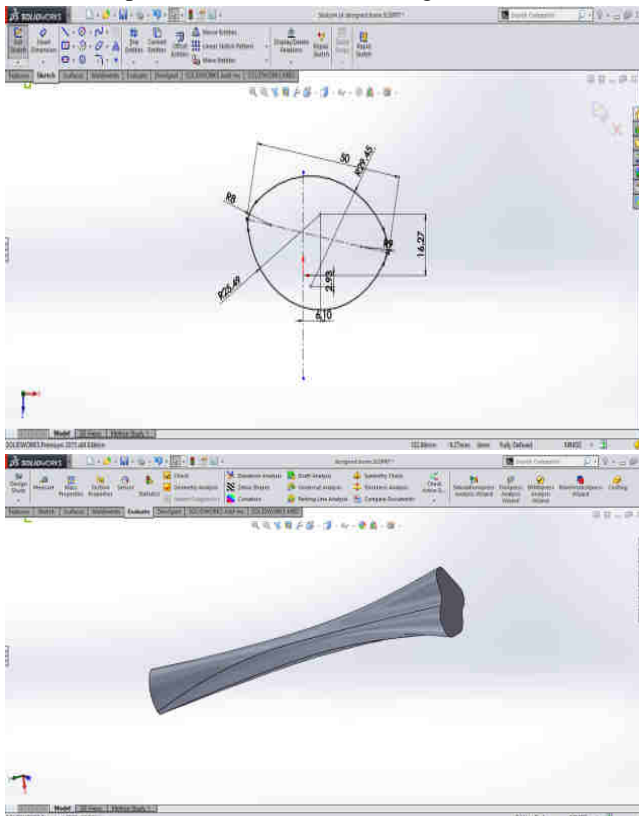


Fig.7: Sketch of lower end of tibia of femur bone cross section

Using the command Loft Boss/Base the defined sketches were united to a single solid body. Fourth sketch of lower end of tibia end of femur bone cross section is defined in plane 4 at 420 mm using edit sketch command with curve and spline features are used in Fig.7. An axial plane as shown is defined and using a sketch drawn in plane 5 and using command revolve Boss/Base, the shape of femur bone is defined in Fig.8.

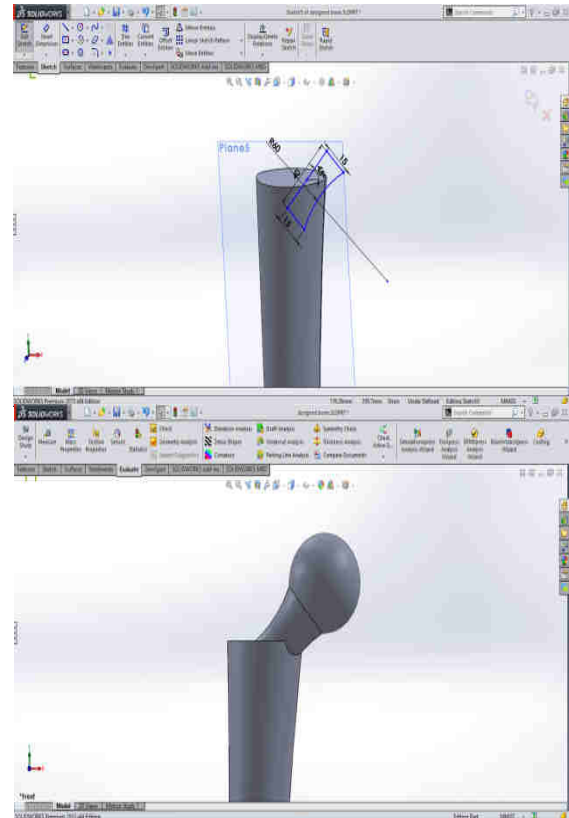
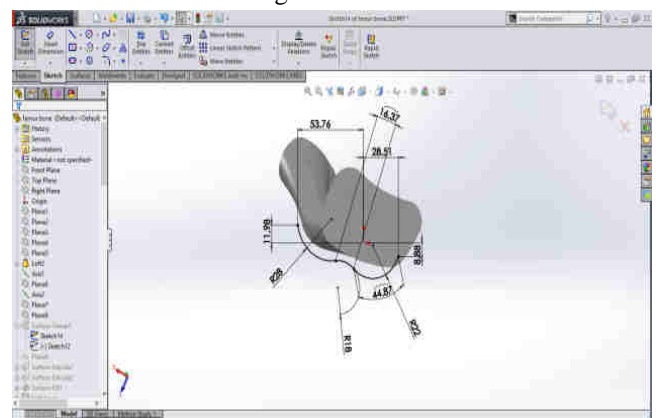


Fig.8: Solid model of femur head

At that feature a secondary shape was attached by dome command with radius of 25mm as shown in Fig.8. For the bottom tibia end of femur bone surface sweep was done with the profiles as shown in Fig.9. The surface is converted into solid using surface thicken command.



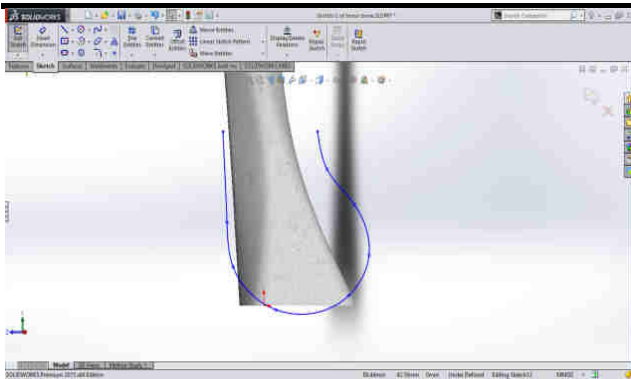


Fig.9: Solid model of bottom tibia end of femur bone

Using various surface shaping tools like fillet, Dome, surface cut etc. were used to obtain a shape close to real bone as shown in Fig.9 and Fig.10.

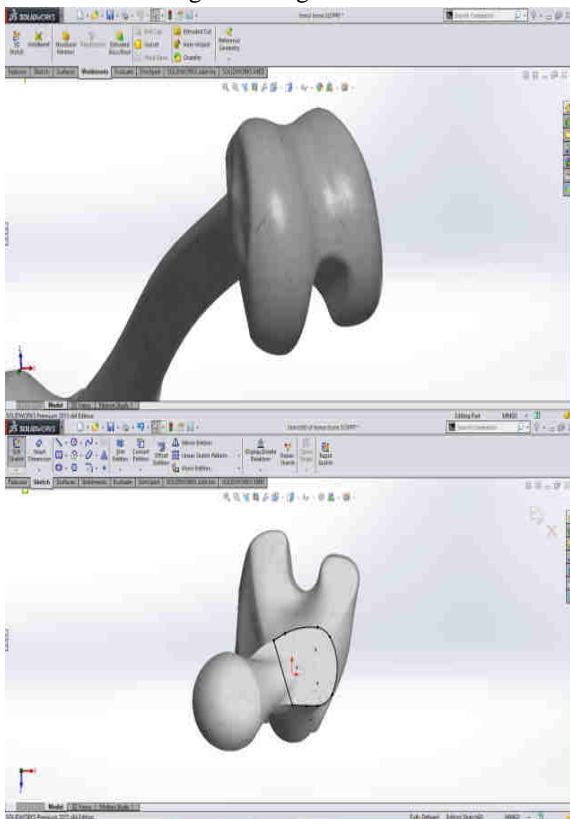


Fig.10: Solid model of tibia end of femur

To create the part of femur head near the vertical diameter and neck vertical diameter by using Loft Base/Base is drawn with following profiles.

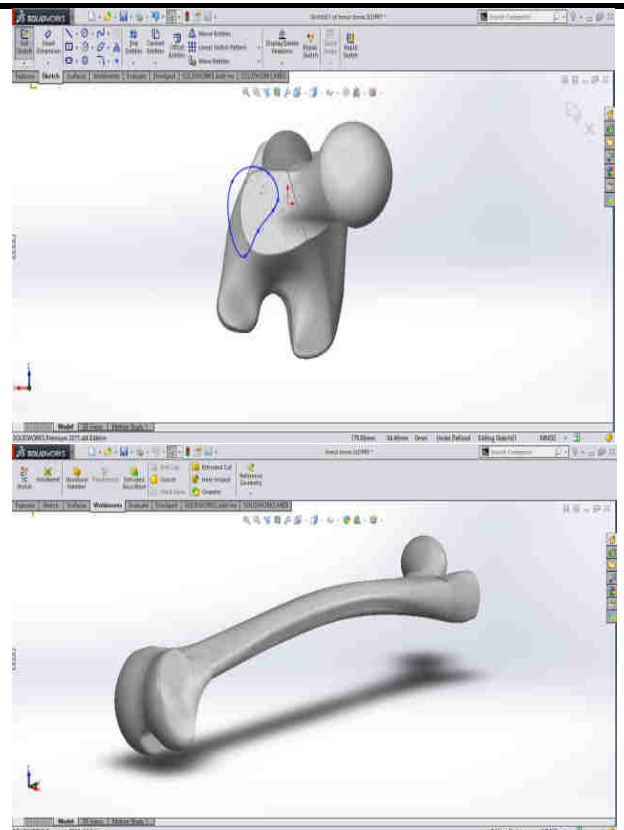


Fig.11: femur head near the neck vertical diameter & three dimension model generated in solid works software

Using supporting features like dome, fillet, at various positions are used to make it closer to a real femur bone and analysis of the same is done in Fig.11.

2.3 Design of prosthetic bone plate

The prosthetic bone plate is designed according to the plate available in market. The dimensions are measured exact by precise measuring instruments like micrometer, venire caliper and radius gauge. Measured dimension of the prosthetic plate [5] is shown as followings:

- Length of plate $L = 165$ mm
- Width of plate $B = 16$ mm
- Thickness of plate $T = 5$ mm
- Thickness of bottom edge of plate from top plane $T_1 = 5.85$ mm
- Radius of screw hole $R = 2.75$ mm
- Radius of wire hole $R_1 = 2.34$ mm
- Width of screw hole $B_1 = 7.18$ mm
- Length of screw hole $L_1 = 8.23$ mm

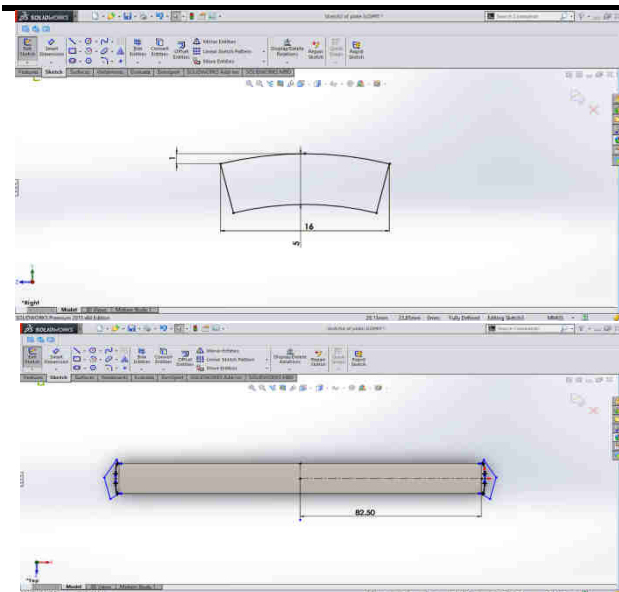


Fig.12: Side view shows the curvature in plate & plate with extrude cut

A fine observation was made on the curves present on the plate as shown in Fig.12. The design starts with using Extrude Boss/Base of the sketch. To give proper edge to plate, extrude cut is used with the profile as shown in Fig.13. The slots present on the plate were patterned linearly as shown in Fig.14. The sketches used for extrude cut are shown. The distance of linear pattern is taken as 31.6mm, which was measured accurately from the real plate and the pattern is mirrored about a symmetrical plane as shown in Fig.15

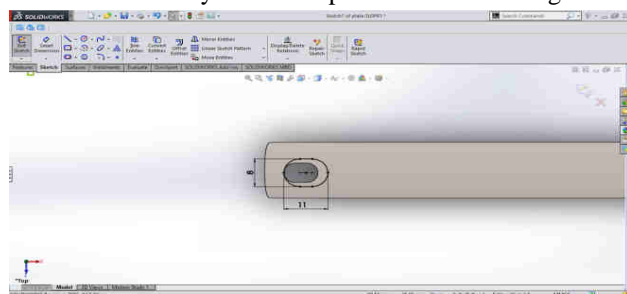


Fig.13: Oval hole is cut into the plate

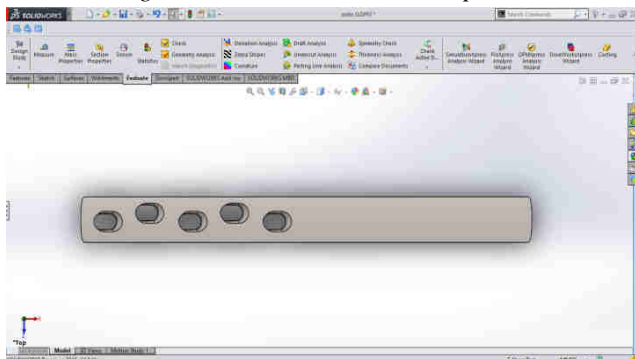


Fig.14: Linear pattern on one side of plate

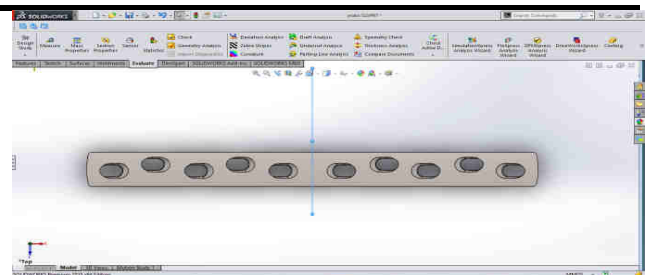


Fig.15: Pattern is mirrored about a symmetrical plane

The two selected grooves in below figure were made by using feature extrude cut with a circle of diameter 2.35mm as shown in Fig.16.

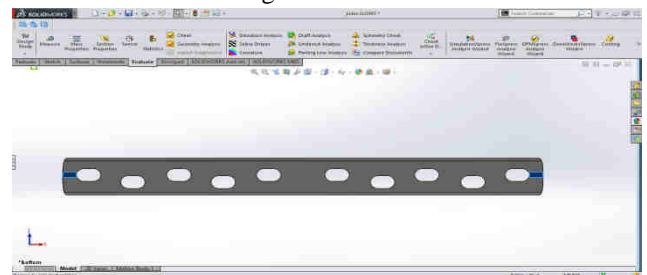


Fig.16: The prosthetic bone plate bottom & top view

2.4 Design of screw

The bolts used for connecting the plate and the bone together are available with a standard diameter of 5mm in different lengths which can be used according to area of need. The bolts are used in design are all of 38mm in length. The design is done according to precise measurements taken from the actual bolt. The sketch of the profile of bolt is drawn as shown in Fig.17 and the feature Revolve Boss/Base was used to create an axially symmetrical bolt as shown in Fig.18. Dimension of screw is [5] shown as per following:

- Minor diameter $d_1 = 4.5$ mm
- Major diameter $d_2 = 5.3$ mm
- Pitch $p = 1.92$ mm
- Shank length $l = 33.74$ mm
- Over length $L = 37.84$ mm
- Thread angle $\alpha = 30^\circ$

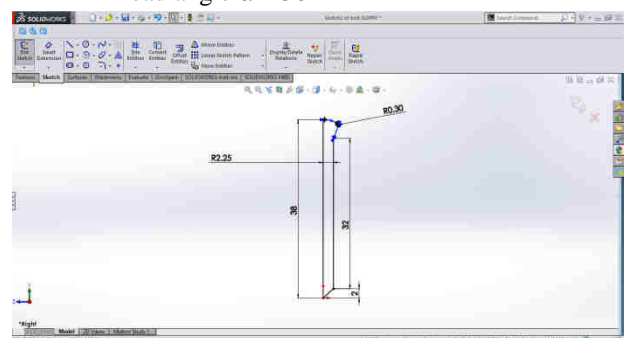


Fig.17: Sketch of bolt cross-section

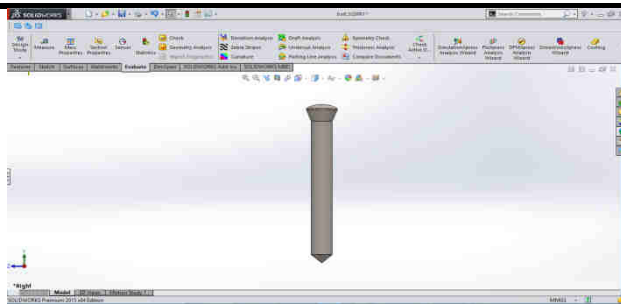


Fig.18: Model of locking screw

2.5 Dimension of the assembled model of femur bone, plate and screw

After modeling of femur bone, prosthetic plate and screw, assembly will be able to produce in the Solid-works. Than assembly is imported in ANSYS software with and without fracture in femur bone as shown in Fig.19.

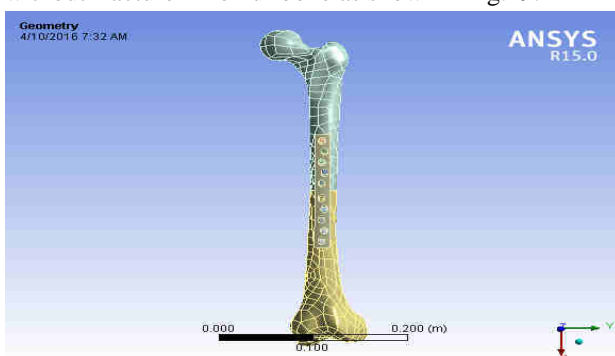


Fig.19: Geometry of assembled view in ANSYS software

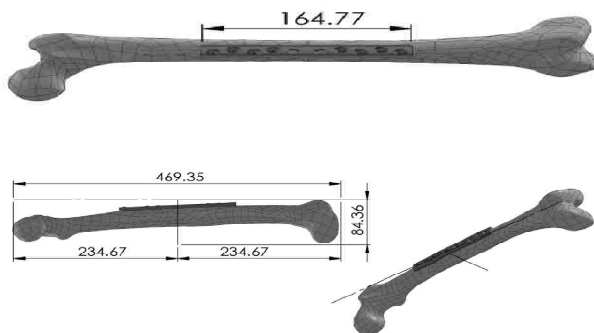


Fig.20: Three dimensional views of assembled model

Holes at middle of the plate are considered empty for proper distribution of load through the screws and plate. Length of the screw should not cross the lateral side of the bone. Plate is fixed at the tensile curve of the femur bone because after load is applied at the femur head, tensile surface of bone will try to come in compressive stresses to balance the stresses properly. Alternate fixing of screws is also possible for reducing the pre-tightening stress in the plate and bone. During implant assembly should be done in such a way that maximum stress is transferred to the screws because plate is implanted only for supporting the femur bone so that femur bone is contacted with minimum stress.

III. CONCLUSION

The femur bone model was obtained with the mass properties and the femur had in that moment the same inertial characteristics. Using the command tools/mass properties was obtained a mass of 650.56 grams and a medium density of the $2.e-006 \text{ kg mm}^{-3}$. The graphical model of femur was prepared for finite elements analysis in structural static or dynamic analysis.

IV. ACKNOWLEDGEMENT

I would like to express my gratitude to **Prof. (Dr.) Manish Bhargava** for his valuable guidance, motivation, encouragement and support given to me during this project. I am very much grateful to him for discussions, which helped greatly to clarify my thoughts. I also give special thanks to **Mr. MohitSoni** (Mechanical Engineering final year student, SKIT, Jaipur) who helped me to generate three dimension modeling of bone and plate by giving his valuable suggestions.

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